Minimal difference between aerobic and progressive resistance exercise on metabolic profile and fitness in older adults with diabetes mellitus: a randomised trial

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Question: Is progressive resistance training as effective as aerobic training of similar duration in sedentary older adults with diabetes mellitus? **Design**: A randomised trial with concealed allocation, assessor blinding and intention-to-treat analysis. **Participants:** Sixty people with Type 2 diabetes mellitus with glycosylated haemoglobin (HbA1c) between 8% and 10% in the past month. **Intervention**: One group undertook progressive resistance exercise and the other group undertook aerobic exercise. Both groups completed 18 sessions over 8 weeks. In each session, the progressive resistance exercise group did nine resistive exercises while the aerobic exercise group did 50 minutes of aerobic exercise. **Outcome measures**: HbA1c, blood glucose, lipid profile (total, high- and low-density cholesterol and triglycerides), weight, body mass index, body fat, waist circumference, waist:hip ratio, blood pressure, and peak oxygen consumption. **Results**: Forty-nine (82%) participants completed the intervention. HbA1c reduced by a similar amount in both groups (MD 0.1%, 95% CI –0.3 to 0.5). However, significant between-group differences occurred in change in waist circumference in favour of progressive resistance exercise (MD –1.8 cm, 95% CI –0.5 to –3.1), and in change in peak oxygen consumption in favour of aerobic exercise (MD 5.2 ml/kg, 95% CI 0.0 to 10.4). **Conclusions**: Progressive resistance exercise has similar effects to aerobic exercise and therefore offers a useful alternative for patients unable to participate in aerobic exercise. **Trial registration**: NCT01000519. **[Ng CLW, Goh SY, Malhotra R, Østbye T, Tai ES (2010) Minimal difference between aerobic and progressive resistance exercise on metabolic profile and fitness in older adults with diabetes mellitus: a randomised trial. *Journal of Physiotherapy* 56: 163–170]**

Key words: Diabetes mellitus, Type 2; Exercise; Hemoglobin A, glycosylated

Introduction

More than 100 million people in Asia were living with diabetes mellitus in 2007 (Chan et al 2009). In Singapore, the ageing of the population together with the rise in rates of obesity and sedentary lifestyle parallelled the rise of Type 2 diabetes mellitus. The prevalence of Type 2 diabetes mellitus in 2004 was 8.2% in adults aged 18 to 69 years (Lim et al 2004). Diabetes doubles the risk of cardiovascular disease (Wang et al 2005) and, in Singapore, one-third of patients developing cardiovascular disease were reported to have underlying Type 2 diabetes mellitus (Lee et al 2001). Singaporeans have a higher percentage of body fat for the same body mass index as Caucasians (Deurenberg- ap et al 2003), and those with Type 2 diabetes mellitus have significantly higher body mass index and waist:hip ratio compared with healthy adults (Lim et al 2004).

Aerobic exercise is known to reduce weight and maintain good glycaemic control, and thus reduce the risk of cardiovascular disease among diabetic patients (Lee et al 2001). Studies involving exercise as a therapeutic intervention in patients with Type 2 diabetes mellitus have focused primarily on aerobic training (Boule et al 2003, Snowling and Hopkins 2006). The beneficial effects of aerobic training on the metabolic profile include reduced HbA1c, lowered blood pressure and resting heart rate, improved cardiac output and oxygen extraction, favorable lipid profile, and reduction of weight and waist circumference (Albright et al 2000, Boule et al 2001, Lim et al 2004, Sigal et al 2007, Snowling and Hopkins 2006, Tresierras and Balady 2009).

In spite of the reported beneficial effects of aerobic exercise on cardiovascular and metabolic parameters, adoption of aerobic activities may be difficult for some patients with Type 2 diabetes mellitus, especially those who are older and obese (Willey and Singh 2003). In the last decade, there has been increasing interest in the role of resistance exercise in the management of diabetes as it appears to improve insulin sensitivity (Tresierras and Balady 2009). While the American College of Sports Medicine recommended resistance exercise at least twice a week (Albright et al 2000), the American Diabetes Association recommended it three times per week. These recommendations were based primarily on findings from two trials comparing aerobic and resistance exercise (Cauza et al 2005, Dunstan et al 2002). However, neither study attempted to make the modes of exercise comparable in intensity or duration. Furthermore, some studies have included both modes in the same intervention arm (Cuff et al 2003, Maiorana et al 2000), thus limiting our ability to compare the two. Other data suggest that progressive resistance exercise has benefits in the treatment of Type 2 diabetes (Neil and Ronald 2006, Irvine and Taylor 2009). However, two studies showed that a home-based resistance exercise program had no effect on glycaemic control (Dunstan et al 2005, Cheung et al 2009). Therefore, there is a need to further study the relative benefits of aerobic exercise and progressive resistance exercise in patients with Type 2 diabetes mellitus.

The research question for this study was:

> Is progressive resistance training as effective as aerobic training of similar intensity and duration in terms of glycaemic, metabolic, anthropometric, and cardiovascular variables in sedentary older adults with Type 2 diabetes mellitus?

Method

Design

A randomised trial was conducted with participants recruited from the Diabetes Centre of Singapore General Hospital. After baseline measurements of glycaemic, metabolic, anthropometric, and cardiovascular profile were taken, participants were randomised to either an experimental (progressive resistance exercise) or a control (aerobic exercise) group, based on a computer-generated assignment schedule that was kept by a physician not involved in the selection of the participants. Allocation was concealed by investigators making telephone contact with the physician who was the only person with access to the assigned schedule. All outcome measures were taken at the end of the 8-week intervention period by an independent assessor who was blinded to group allocation. Outcomes were measured between 36 and 48 hours after the last exercise session. All participants were specifically told not to discuss any aspect of their training with the assessor. The templates developed by the Research on Research group were used to facilitate communication with the statistician regarding data analysis and in the writing of the manuscript (Pietrobon et al 2004, Shah et al 2009).

Participants

Patients were included if they were aged 50 years or above, had glycosylated haemoglobin (HbA1c) levels between 8% and 10% in the past month, and were able to walk continuously for at least 20 min and climb one flight of stairs unaided without stopping. They were also required to be sedentary, defined as reporting never having participated in a structured exercise program or recreational physical activity or sport. Subjects were excluded if they had: uncontrolled diabetes mellitus with HbA1c more than 10% or if escalation of treatment of glycaemic control or dyslipidaemia was likely to be necessary over the 8-week trial period; congestive cardiac failure, unstable angina, or acute myocardial infarction within the last year; proliferative diabetic retinopathy; uncontrolled hypertension; advanced arthritis likely to limit mobility or participation in prescribed exercises; respiratory co-morbidities; significant proteinuria or chronic renal insufficiency; been prescribed a very low caloric diet (less than 1000 kcal/day) or drugs for the treatment of obesity; renal disease; or inability to monitor glucose level or to comply with the exercise program. Recruited participants gave informed consent and their physicians were informed about the research protocol and that there should be no escalation of medical treatment during the 8-week intervention period.

Intervention

The experimental group (progressive resistance exercise) undertook nine resistive exercises using a combination of machines and free weights (Box 1) at 65% of their assessed one repetition maximum (1RM) as recommended by American College of Sports Medicine (Ratamess et al 2009). The 1RM for each muscle group was determined using a prediction formula (Brown and Weir 2001) by assessing the number of repetitions that the participant was able to complete at submaximal loads. The progressive resistance exercise intervention is presented in Table 1.

Box 1. Resistance exercises.

Muscle group	Description
Quadriceps	***Seated leg press***: Seated upright with feet onto a plate, the participant pushed against the load extending and flexing the knee.
	Straight leg raise: Lying on the back with one leg bent and one leg straight with the pelvis posteriorly tilted, the participant lifted the straightened leg up to approximately 45 degrees and slowly lowered it back to the plinth.
Hamstrings	***Hamstrings curl machine***: Lying prone with hips flush against the bench, the calf was placed under the roller and the leg curled the weight up to 90 degrees from the machine and was then lowered down slowly.
Biceps	***Biceps curls***: The participant held the dumb-bells with palms faced out, elbows next to the body and curled the weights towards the shoulders and then lowered them slowly.
Triceps	***Triceps curls***: Arms were raised straight overhead while keeping them close to the ears and elbows bent, lowering the dumb-bells behind the participant's head. The elbows were straightened to raise the weights and bent to lower them again.
Deltoids	***Lateral raises (middle deltoids)***: The dumb-bells were held in front of the hips with palms facing each other and elbows slightly bent. The weights were then raised out to the sides and upwards in a semi-circular manner to just above the shoulder level and then lowered slowly.
	Front raises (anterior deltoids): The dumb-bells were held in front on the body with palms facing each other and elbows slightly bent. The weights were then raised out to the front and upwards in a semi-circular manner to just above the shoulder level and then lowered slowly.
Gluteus	***Hip abduction***: The outside of the thigh was placed against the roller pad and raised against the roller pad to the side and returned to initial position while body weight was on the other leg.
	Hip extension: The back of the thigh was placed against the roller pad and raised against the roller pad to the back by extending hip and straightening leg and returned to initial position while body weight was on the other leg.

The control group (aerobic exercise) underwent 50 minutes of aerobic training involving treadmill, elliptical cycle, and stationary bicycle exercise, with a target heart rate of 65% of their age-predicted maximum heart rate, after being assessed by a submaximal treadmill test according to American College of Sports Medicine guidelines.

Both groups were progressed after 4 weeks of training to 70% of their predicted 1RM or age-predicted heart rate depending on grouping. The metabolic equivalents (METs) for both the aerobic exercise and progressive resistance

Table 1. Details of the aerobic exercise and progressive resistance exercise interventions.

	Progressive resistance exercise	Aerobic exercise
Intensity	65–70% of 1RM	65–70% maximum heart rate as determined by the modified Bruce protocol test
Duration	One set of 10 repetitions for each of the 9 resistive exercises completed in a circuit 3 rounds of the circuit were completed in a maximum of 50 minutes	50 minutes (10 minutes on upright or recumbent bicycle and 20 minutes each on the treadmill and elliptical cycle)
Type/Mode	Quadriceps (seated leg press machine and straight leg raises) Hamstrings (hamstring curls machine) Biceps, triceps, anterior and middle deltoids (using free weights) Hip abductors and extensors (gluteal machine)	Treadmill, stationary upright bicycle, stationary recumbent bicycle, cross trainer (elliptical cycle)
	Both interventions	
Before exercise	Heart rate, blood pressure and glucose level (pin prick)	
Warm up	3 min of stretches of quadriceps, hamstrings, calf, biceps, triceps and back, with each muscle group stretched twice, holding each stretch for 15 s 10 min of unloaded cycling	
Program	8-week group exercise program at Singapore General Hospital Physiotherapy Gym	
Frequency	2 to 3 times a week, Mondays, Wednesdays and Fridays	

exercise training were estimated to be approximately 3.5 in accordance with the compendium of METs provided by the American College of Sports Medicine (ACSM 2000), a value defined as moderate intensity (Pate et al 1995). The aerobic exercise intervention is presented in Table 1.

All participants wore a heart rate monitor during the warm-up and exercise program and were supervised in their exercises in a group. Each participant was scheduled to complete 18 exercise sessions over 8 weeks at a frequency of 2 to 3 times a week.

Outcomes measures

The primary outcome measure was HbA1c. Secondary outcomes included blood glucose, lipid profile, and anthropometric and cardiovascular measures. Adverse events were also recorded. All outcome assessors were blinded to group allocation.

HbA1c was measured using 10 ml of blood drawn from participants who fasted at least 10 h from the night before and analysed at the Biochemistry Laboratory of the Pathology Department in Singapore General Hospital by laboratory assistants who were also blinded to the project. HbA1c was measured using high performance liquid chromatography with a coefficient of variation (CV) of 2.4% at 5.1% (HbA1c) and a CV of 1.9% at 9.6% (HbA1c).

Glucose was measured using the glucose oxidase method with a CV of 1.6% at 3.3 mmol/L and a CV of 1.1% at 18.8 mmol/L.

The lipid profile comprised total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Total cholesterol and triglycerides were measured using enzymatic colorimetric methods with cholesterol oxidase-peroxidase amino phenazone phenol and glycerol-3-phosphate oxidase-peroxidase amino phenazone phenol. The CV for cholesterol is 1.9% at 3.22 mmol/L and 1.3% at 7.72 mmol/L. The CV for triglyceride is 1.8% at 1.02 mmol/L and 1.4% at 2.27 mmol/L. HDL-C was measured using homogenous enzymatic colorimetric assay with a CV of 4.8 % at 0.93 mmol/L and 3.7 % at 2.06 mmol/L. LDL-C was calculated using the Friedewald formula.

Anthropometric measurements included weight, body mass index, body fat measured by skin fold and by bioimpedance, waist circumference and waist:hip ratio. Body mass index was calculated as weight in kg divided by the square of height in m. Skin-fold thickness was measured at four sites: biceps, triceps, sub-scapular, and suprailiac, on the right side of the body (Heyward 2002), and percentage body fat was estimated using a formula applicable to Singaporeans (Deurenberg- ap et al 2003). Percentage body fat was also measured using two-point bioimpedance analysis[a] and a regression equation based on measured resistance and reactance. Waist circumference was measured with a tape placed horizontally at the mid-point between the iliac crest and the lower aspect of the floating ribs in the mid axillary line, at the end of normal expiration. Hip circumference was measured at the mid point of the gluteal region.

Cardiovascular measures included peak oxygen consumption and resting blood pressure. Peak oxygen consumption was measured during a submaximal exercise test using a Modified Bruce protocol (ACSM 2000) with 12-lead electrocardiogram and with monitoring of blood pressure. The treadmill test was terminated if the participant (i) reached his or her peak oxygen consumption or predicted maximum heart rate, (ii) indicated that he or she could not continue the testing, (iii) had systolic blood pressure above 220 mmHg or diastolic blood pressure above 100 mmHg, or (iv) developed abnormal electrocardiographic changes.

Data analysis

For sample size calculation, we adopted a 1% difference in HbA1c as clinically worthwhile because an increase of

Table 2. Baseline characteristics of participants, therapists and centres.

Characteristic	Participants			
	Randomised (n = 60)		Lost to follow-up (n = 11)	
	Exp (n = 30)	Con (n = 30)	Exp (n = 5)	Con (n = 6)
Participants				
Age *(yr)*, mean (SD)	57 (7)	59 (7)	56 (7)	56 (7)
Gender, n male (%)	11 (37)	8 (27)	3 (60)	2 (33)
Chinese ethnicity, n (%)	22 (73)	17 (57)	1 (20)	1 (17)
Highest education level, n (%)				
Primary	8 (27)	9 (30)	1 (20)	1 (17)
Secondary	15 (50)	16 (53)	4 (80)	4 (67)
Tertiary	7 (23)	5 (17)	0 (0)	1 (17)
Duration of diabetes (yr), mean (SD)	11 (9)	12 (9)	7 (9)	9 (4)
Medication*, n (%)				
Sulphonylurea	15 (50)	18 (60)	0 (0)	0 (0)
Metformin	24 (80)	25 (83)	3 (60)	6 (100)
Glitazone	10 (33)	8 (27)	0 (0)	0 (0)
Alpha glucosidase	5 (17)	7 (23)	0 (0)	0 (0)
Combination of oral hypoglycaemic agent and insulin	8 (27)	8 (27)	2 (40)	0 (0)
Therapists				
Participants treated, n (%)				
Therapist 1	15 (50)	15 (50)	2 (40)	3 (50)
Therapist 2	15 (50)	15 (50)	3 (60)	3 (50)

Exp = experimental group, Con = control group, * = not mutually exclusive

1% is associated with an 18% increase in the relative risk of cardiovascular disease in patients with Type 2 diabetes mellitus (Selvin et al 2004). Most studies in the systematic review by Irvine and Taylor (2009) reported a standard deviation of HbA1c between 1.0% and 1.7%. Therefore, we anticipated a standard deviation of 1.35%. A total of 30 patients per group would provide an 80% probability of detecting a difference of 1% in HbA1c at a two-sided 5% significance level, assuming a standard deviation of 1.35%. Therefore we sought to recruit 60 participants.

All participants with follow-up data were analysed according to their group allocation, ie, using an intention-to-treat analysis. Baseline values of the various outcome parameters were carried forward for the 11 participants who dropped out during the intervention. The difference in change from baseline to post-intervention between the aerobic exercise and progressive resistance exercise groups for each outcome was assessed using an independent t-test. Statistical significance was set at p 0.05, so results are presented as a mean difference (95% CI).

Results

Flow of participants and therapists through the trial

Five hundred and thirty patients diagnosed with Type 2 diabetes mellitus attending the Diabetes Centre at Singapore General Hospital were screened for eligibility between October 2003 and October 2004. Sixty-eight patients met the eligibility criteria, of whom 60 patients gave informed consent to participate in the study and were randomised, with 30 being allocated to each group. The flow of participants through the trial and reasons for exclusion are presented in Figure 1. The baseline characteristics of the participants who completed the study and those lost to follow-up are presented in Table 2. Both groups were comparable and the participants lost to follow-up were comparable to those who completed the study.

Two physiotherapists with 3 years experience supervised the exercise sessions at the Physiotherapy Outpatient Department in Singapore General Hospital.

Compliance with trial method

Forty-nine (82%) participants completed all 18 sessions within 8 weeks. Eleven participants (5 in the progressive resistance exercise group and 6 in the aerobic exercise group) failed to attend for the full exercise program and declined to attend for further measurement. No changes in medication were prescribed for the study participants during the intervention period.

Effect of intervention

Group data for all outcomes are presented in Table 3. Individual data are presented in Table 4 (see eAddenda for Table 4). The change in HbA1c was similar in both groups. It reduced by 0.4% (SD 0.6) in the progressive resistance exercise group and by 0.3 % (SD 0.9) in the aerobic exercise group, which was not a statistically significant difference (MD –0.1%, 95% CI –0.5 to 0.3).

Three of the secondary outcomes had significant between-group differences: waist circumference, peak oxygen consumption, and resting systolic blood pressure. The between-group difference in the change in waist

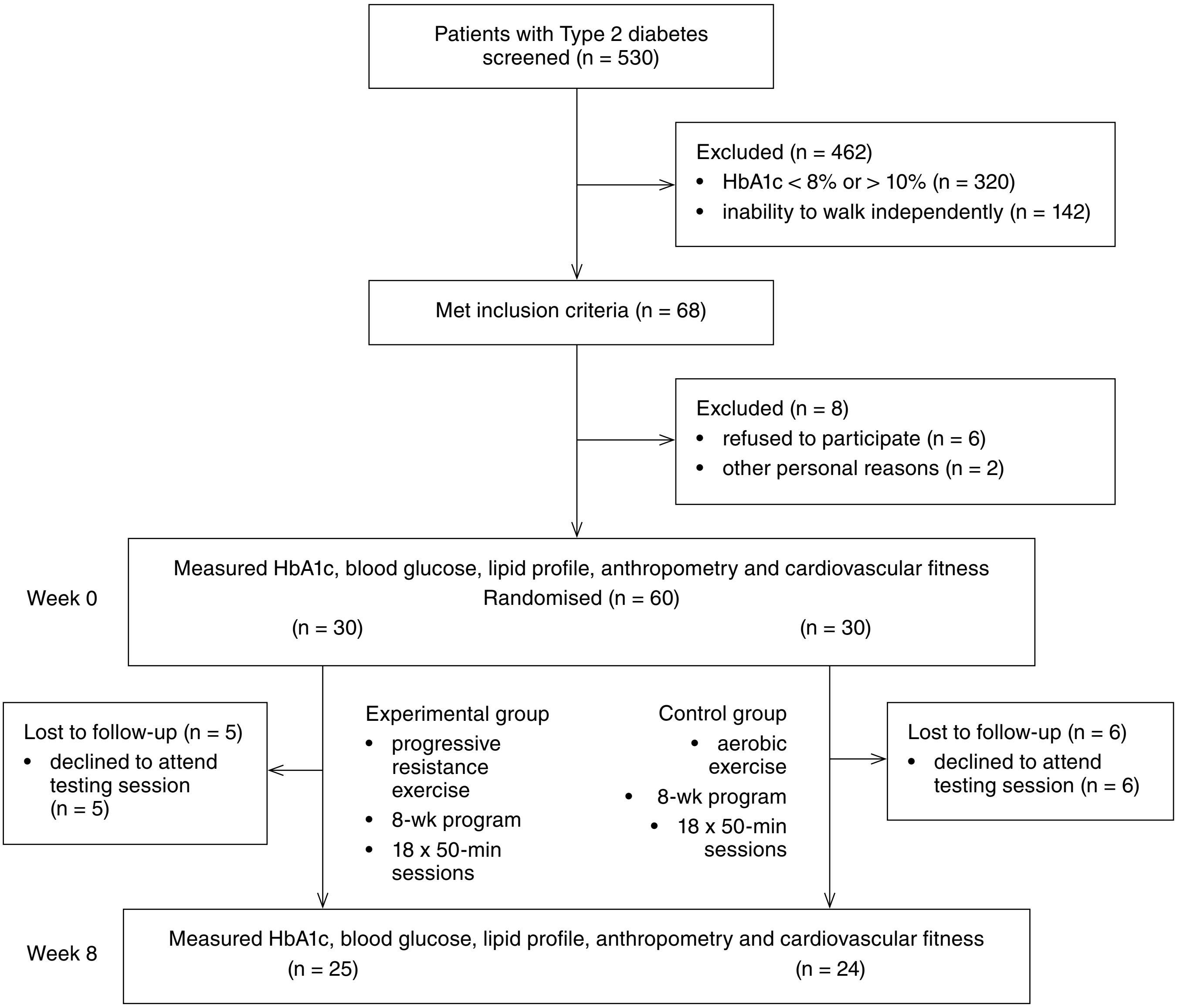

Figure 1. Design and flow of participants through the trial.

circumference favoured the progressive resistance group (MD –1.8 cm, 95% CI –0.5 to –3.1). The between-group difference in the change in peak oxygen consumption favoured the aerobic group, improving by a mean of 5.2 ml/kg (95% CI 0.0 to 10.4) more than in the progressive resistance exercise group. The reduction in resting systolic blood pressure was significantly greater in the aerobic exercise group than in the progressive resistance exercise group (MD 9 mmHg, 95% CI 2 to 16).

Discussion

Comparison of the two modes of exercise was the primary aim of the study, so the exercise regimens were matched as closely as possible for frequency, intensity, duration, and rate of progression. Because all participants in both groups who attended the exercise sessions were able to cope with the prescribed regimen, this strengthens the interpretation that between-group differences did reflect the relative effects of the two exercise modes. Furthermore, although there were some dropouts, the resulting reduction in statistical power was offset by the smaller than anticipated standard deviation in HbA1c in our cohort, at 1.21%. Therefore the study had sufficient power to exclude clinically worthwhile differences between the therapies on the primary outcome. Because very few significant between-group differences were identified and the confidence intervals around the between-group differences were generally narrow, progressive resistance exercise is likely to be a similarly effective alternative to aerobic exercise.

Two previous randomised trials comparing progressive resistance exercise and aerobic exercise reported better improvement in HbA1c with resistance exercise (Arora et al 2009, Cauza et al 2005). However, one trial did not describe the training programs in terms of intensity or volume (Cauza et al 2005), so it is difficult to determine the source of the between-group differences. The other trial had a small sample size (n = 10) in each arm and a wide (5% to 10%) baseline HbA1c (Arora et al 2009), so the current trial may provide more robust data. A recent meta-analysis showed that the patients randomised to resistance exercise tend to spend more time on training than the aerobic exercise group (Gordon et al 2009). A systematic review showed that resistance exercise alone reduced HbA1c by 0.3% but was not significantly different when compared to aerobic

Table 3. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups.

Outcome	Groups				Difference within groups		Difference between groups
	Week 0		Week 8		Week 8 minus Week 0		Week 8 minus Week 0
	Exp (n = 30)	Con (n = 30)	Exp (n = 30)	Con (n = 30)	Exp	Con	Exp minus Con
HbA1c *(%)*	8.9 (1.5)	8.5 (0.9)	8.4 (1.2)	8.1 (1.1)	–0.4 (0.6)	–0.3 (0.9)	–0.1 (–0.5 to 0.3)
Blood glucose *(mmol/L)*	10.4 (3.1)	9.5 (2.5)	10.1 (3.6)	9.3 (2.2)	–0.3 (2.8)	–0.2 (1.7)	–0.1 (–1.3 to 1.1)
Lipid profile							
Total cholesterol *(mmol/L)*	5.4 (1.6)	5.1 (0.9)	5.5 (1.6)	5.1 (1.1)	0.0 (0.8)	0.0 (0.6)	0.0 (–0.3 to 0.4)
Triglycerides *(mmol/L)*	3.1 (3.6)	1.8 (0.8)	3.5 (6.5)	1.8 (0.8)	0.4 (3.2)	0.0 (0.4)	0.4 (–0.8 to 1.6)
High density lipoprotein *(mmol/L)*	1.3 (0.4)	1.4 (0.4)	1.4 (0.4)	1.4 (0.4)	0.1 (0.2)	0.0 (0.1)	0.1 (0.0 to 0.2)
Low density lipoprotein *(mmol/L)*	3.1 (1.5)	2.8 (0.9)	3.0 (1.4)	2.8 (1.0)	–0.1 (0.5)	–0.0 (0.6)	0.0 (–0.3 to 0.2)
Anthropometric							
Weight *(kg)*	69.5 (14.2)	70.3 (13.8)	69.7 (14.4)	70.2 (13.6)	0.2 (1.1)	0.0 (1.4)	0.2 (–0.4 to 0.9)
BMI *(kg/m^2)*	27.4 (4.7)	27.8 (5.2)	27.5 (4.7)	27.8 (5.2)	0.1 (0.4)	0.0 (0.5)	0.1 (–0.2 to 0.3)
Percentage body fat – skinfold *(%)*	33.9 (7.8)	35.3 (6.3)	32.7 (7.4)	34.3 (5.9)	–1.3 (2.2)	–1.1 (2.2)	–0.2 (–1.3 to 0.9)
Percentage body fat – bioimpedance *(%)*	33.1 (6.2)	33.9 (5.2)	31.6 (6.1)	32.8 (5.3)	–1.4 (2.4)	–1.1 (2.2)	–0.3 (–1.5 to 0.9)
Waist circumference *(cm)*	90.8 (11.2)	91.9 (11.6)	89.2 (11.7)	92.1 (11.0)	–1.6 (2.6)	0.2 (2.4)	–1.8 (–0.5 to–3.1)
Waist:hip ratio	0.92 (0.08)	0.91 (0.06)	0.90 (0.07)	0.91 (0.05)	–0.02 (0.05)	0.00 (0.03)	–0.02 (–0.04 to 0.00)
Cardiovascular							
Peak volume of oxygen consumed *(ml/kg)*	32.8 (17.8)	32.3 (15.5)	37.3 (17.5)	42.0 (12.8)	4.5 (9.4)	9.8 (10.7)	–5.2 (–10.4 to 0.0)
Resting systolic blood pressure *(mmHg)*	123 (12)	133 (14)	123 (11)	123 (13)	–1 (12)	–9 (14)	9 (2 to 16)
Resting diastolic blood pressure *(mmHg)*	76 (9)	78 (11)	76 (10)	74 (11)	0 (9)	–4 (12)	4 (–1 to 10)

Exp = experimental group (progressive resistance exercise), Con = control group (aerobic exercise), HbA1c = glycosylated haemoglobin, BMI = body mass index

exercise (Irvine and Taylor 2009). Our study showed that, controlling for exercise volume, duration, and intensity, aerobic exercise and progressive resistance exercise had similar improvement. The degree of change in HbA1c seen in both groups in our study was similar to that seen with oral medications and diet (Irvine and Taylor 2009).

Despite similar effects on body fat percentage, progressive resistance exercise resulted in a greater reduction in waist circumference than aerobic exercise – a finding in line with a previous study showing that progressive resistance exercise reduced visceral and subcutaneous abdominal fat (Ibanez et al 2005). The different exercise physiology and mechanisms of action of progressive resistance exercise and aerobic exercise may have also played a role. Progressive resistance exercise increases muscle strength or fat free mass and mobilises visceral adipose tissue, thus enhancing insulin sensitivity (Tresierras and Balady 2009).

Unfortunately, the greater reduction in waist circumference was not also associated with any additional benefit in terms of blood pressure or lipid profile, all of which are closely related parameters. A study on obese Japanese men with metabolic syndrome, which can be considered closest to our population, suggested that a reduction of at least 3cm in waist circumference was required for any change in metabolic profile (Miyatake et al 2008). The average reduction observed for the progressive resistance exercise group in the present study was only about half of that, at 1.6 cm (SD 2.6).

The effect of aerobic exercise on peak oxygen consumption was significantly greater than that of progressive resistance exercise. Previous studies showed that resistance exercise can elicit modest improvement in peak oxygen consumption, by approximately 6% (ACSM 1998). The progressive resistance exercise group in our study improved their peak oxygen consumption by approximately 14%, comparable to that observed in a previous 6-month study on progressive resistance exercise on cardiorespiratory fitness in elderly men and women (Vincent et al 2003). This can be attributed to increased lower limb strength (Vincent et al 2003). These improvements may be clinically important as physical activity in patients with chronic conditions can reduce mortality (Martinson et al 2001, Sigal et al 2006).

The training duration of 8 weeks was brief compared to the 12-week regimens examined in earlier studies. The 8-week duration was chosen to minimise or avoid the influence of any medication change during the course of the trial. HbA1c levels reflect glycaemic control over the previous 2 to 3 month period (American Diabetes Association 1995–2010), thus the observed change in HbA1c may not adequately reflect the effect of the interventions on glycaemic control. The recommended frequency of 2 to 3 sessions per week was not adhered to for some participants for reasons such as public holidays, caring for family members, and feeling unwell. Nevertheless, meaningful differences in some parameters were demonstrated between the groups, as well as within each group, similar to those observed in other studies of longer duration. These included improvements in waist circumference and peak oxygen consumption (Vincent et al 2003) and reduction in HbA1c (Boule et al 2003, Boule et al 2001).

As our inclusion criteria included a baseline HbA1c of 8% to 10%, the absence of exercise training would have required an escalation of medical management. Thus, a non-intervention control group was excluded. Though this limits our ability to assess the true benefits of exercise, it was not the aim of the study since the benefits of exercise for Type 2 diabetes mellitus are well established. ■

Footnotes: [a]Biodynamics Model 450, Biodynamic International, USA.

eAddenda: Table 4 available at www.jop.physiotherapy.asn.au

Ethics: The study was approved by Singapore General Hospital (SGH) Institutional Review Board (IRB 253/2002). All participants provided informed consent before data collection began.

Competing interests: Nil

Support: National Medical Research Council of Singapore (www.nmrc.gov.sg NMRC/0728/2003).

Acknowledgements: Abbott Laboratories (Singapore) Pte. Ltd. for supplying the Optium™glucose meter, lancets, and glucose strips for daily monitoring of participants blood glucose level.

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